Infrared Spectroscopy of the High Redshift Radio Galaxy MRC 2025-218 and a Neighboring Extremely Red Galaxy

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Abstract. This paper presents infrared spectra taken with the newly commissioned NIRSPEC spectrograph on the Keck Telescope of the High Redshift Radio Galaxy MRC 2025-218 (z=2.630) and an extremely red galaxy (R-K > 6mag) 9" away. These observations represent the deepest infrared spectra of a radio galaxy to date and have allowed for the detection of Hβ, OIII (4959/5007), OI (6300), Hα, NII (6548/6583) and SII (6716/6713). The Hα emission is very broad (FWHM $\sim$ 6000 km/s) and strongly supports AGN unification models linking radio galaxies and quasars. The line ratios are most consistent with a partially obscured nuclear region and very high excitation. The OIII (5007) line is extended several arcseconds and shows high velocity clouds in the extended emission. The nucleus also appears spectrally double and we argue that the radio galaxy is undergoing a violent merger process. The red galaxy, by comparison, is very featureless even though we have a good continuum detection in the H and K bands. We suggest that this object is a foreground galaxy, probably at a redshift less than 1.5.

1.   Introduction

Deep radio surveys have proven to by one of the best methods for finding high redshift galaxies. Most evidence points towards radio galaxies as precursors to local giant ellipticals (e.g. Pentericci, et al. 1999). Many have irregular and complex morphologies suggestive of mergers and they are often surrounded by an overdensity of compact sources; presumably sub-galactic clumps (e.g. van Breugel et al. 1998). Active galaxy unification models suggest that FRII radio galaxies are quasars with obscured broad line regions. Recent infrared spectroscopic surveys (e.g. Evans 1998) have shown that at redshifts less than
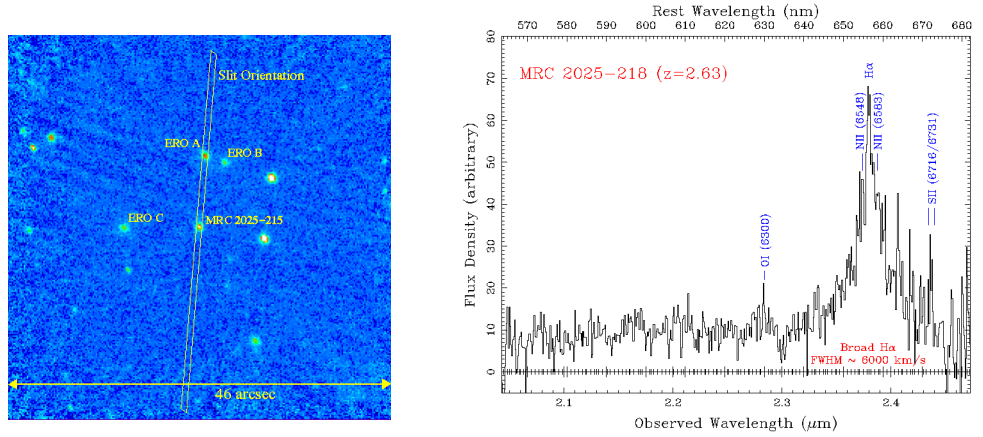
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Figure 1.   The K band image of the MRC 2025-218 field is on the left. The K band spectrum is on the right and is dominated by a very wide ($>$6000 km s^{-1}) strong emission line of Hα.

2.6 roughly have of the radio galaxies show evidence of an active nucleus typically with a Seyfert 2 spectrum.

MRC 2025-218 (z=2.630) has a compact infrared and optical continuum morphology (van Breugel et al. 1998), but extended Lyα emission (5") aligned with its radio axis (McCarthy et al. 1992). McCarthy et al. also found three extremely red galaxies (ERO's: R-K 6 mag) within 20" of the radio galaxy. This is a large overdensity of such objects and strongly suggests and association between the ERO's and the active galaxy.

2.   Observations

The field of MRC 2025-218 was observed on 4 Jun, 1999 (UT) with the near infrared spectrograph NIRSPEC (McLean, et al. 1998) on the Keck II Telescope during its commissioning. First the field was imaged in the K band with the slitviewing camera. Figure 1 shows the reduced image of the field with a total integration time of 540 seconds. As shown in the figure, the slit (42" long and $0''.57$ wide) was placed on both the radio galaxy and the extremely red galaxy dubbed ERO-A by McCarthy et al. (1992).

Four 300 second exposures were taken in both the H-Band ($\sim$1.6μm) and K-Band ($\sim$2.2μm). Due to vignetting at one edge of the slit, half of the exposures on the ERO were lost so the effective integration time on MRC 2025-215 is 20 minutes in each band but only 10 minutes on ERO-A. The seeing was $0''.54$.

3.   Results

Figure 2 shows the H band spectrum of MRC 2025-218. By far the most dominant line is [OIII] (500.7 nm) redshifted to 1.82 μm. This line is highlighted in the right panel of figure 2 where the complete position velocity map of this
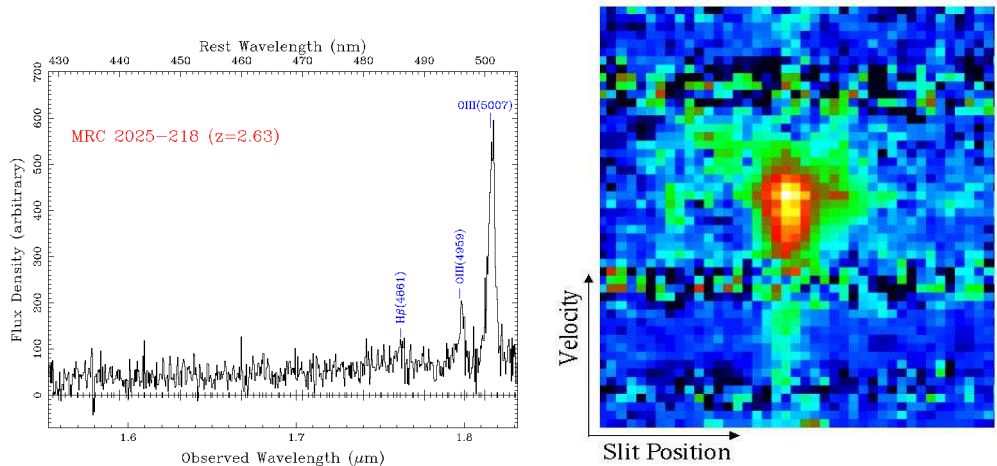
Figure 2. H band spectrum of MRC 2025-218. The right panel is the position-velocity plot of just the OIII line at 500.7 nm.

line is presented. The nucleus has a double peaked structure in [OIII] and Hα (see below) with a separation of 150 km sec^{-1}. Two knots appear at essential 0 km sec^{-1} relative velocity, but 1$\farcs$8 North and 2$\farcs$4 South of the Nucleus. A high speed clump appears 1" North of the nucleus and at a redshifted relative velocity of 410 km sec^{-1}. Also detected in the H band spectrum is the other member of the [OIII] doublet at 495.9 nm, and Hβ. The ratio of [OIII] / Hβ is extremely large at approximately 31$\pm$6. The Hβ line has a total nuclear flux of only 3.4×10^{-17} ergs cm^{-2} s^{-1}.

The right panel of figure 1 shows the K Band spectrum which is dominated by a broad Hα emission line. The line is very non-Gaussian but has a fwhm of the broad line greater than 6000 km sec^{-1}. The narrow component has a similar double peaked profile as the [OIII] line at 500.7 nm. Several other lines are also detected, but only at the few sigma level, including [OI] (630.0 nm), [NII] (654.8/658.3 nm) and [SII] (671.6/673.1 nm). These lines are all much weaker than Hα and the [OI]/Hα ratio for the narrow components is estimated at approximately 0.1 or less.

H and K band spectra of the object labeled ERO-A were taken simultaneously with MRC 2025-218. The spectra have no significant line detections or spectral breaks. In particular no emission lines are observed at similar positions as MRC 2025-218. Given the mild H and K spectral slopes in the spectra and the large r-K color found by McCarthy et al. (1992), we suggest that the ERO is probably at a significantly smaller redshift than the radio galaxy.

4. Discussion & Conclusions

The spectrum of the HzRG MRC 2025-218 is clearly dominated by emission lines from an AGN. The broad Hα emission line is definitive evidence of a type I AGN. The extremely large ratio of [OIII]/Hβ is also found only in true AGN and is in fact greater than in most local Seyfert 1 type galaxies.

The double peak found in both Hα and [OIII] is highly suggestive of a double active nucleus. If the second peak were due to a star forming region it would be unlikely that the [OIII] line would be double as well. The off nucleus knots seen in [OIII] are difficult to understand. Extended [OIII] has been observed in other radio galaxies aligned to the radio axis (Armus et al. 1998). Extended Lyα has also been observed aligned to the radio axis (e.g. Chambers et al., 1996) but the emission mechanism is poorly understood. In the case of [OIII] it is difficult to find a mechanism for its strong production in these off nuclear sites and we believe that the most likely explanation is that we are seeing [OIII] as scattered light originally emitted by the nucleus.

The narrow line ratio of Hα over Hβ is roughly 8 compared with the intrinsic ratio of 3.1 observed in local AGN. If we assume the difference is due to dust extinction then it is consistent with obscuration of $A_V \sim 2$ mag. The fact that Hβ is not broadened and that broad Lyα was not observed in optical spectra implies that the central region is much more obscured. The presence of such an obscured broad line region in a classic radio galaxy strongly supports the AGN unification models and links radio galaxies with radio loud quasars.

The presence of 3 extremely red galaxies discovered within 20" of the radio galaxy is very suggestive of a connection with MRC 2025-218. But if our suggestion is right that the ERO's are at a much lower redshift then their overdensity in this field and their general overdensity in the fields of high redshift quasars and radio galaxies may be due to weak lensing. The connection is that in flux limited surveys you are more likely to discover high redshift objects if there is an overdensity of foreground objects.

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